# Wound Measurement: The Comparative Reliability of Direct Versus Photographic Tracings Analyzed by Planimetry Versus Digitizing Techniques

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ABSTRACT. Lagan KM, Dusoir AE, McDonough SM, Baxter GD. Wound measurement: the comparative reliability of direct versus photographic tracings analyzed by planimetry versus digitizing techniques. Arch Phys Med Rehabil 2000;81:1110-6.

**Objective:** To investigate two methods of wound measurement (planimetry and digitizing) performed on two routinely used techniques of clinical wound assessment, tracings taken directly from a patient's wound (raw tracing) and from photographs of the wound (photographic tracing).

**Design:** We examined the level of repeatability and thus reliability of these methods, and determined if absolute measured wound size differed between the combinations of method and assessment procedures.

**Patients:** Seven patients (4 women, 3 men; mean age ± standard error of the mean = 63.1 ± 5.0yrs) with a total of 11 wounds.

**Setting:** Patients attended a podiatry outpatient department on two separate days for raw and photographic tracing of their wounds. For both of these trace types, a series of repeated recordings were conducted by a single investigator using planimetry and digitizing measurement methods.

**Main Outcome Measure:** Independent statistical analyses (analysis of variance, $p < .05$) were conducted on logged coefficients of variation and logged means data to investigate for repeatability and for size differences, respectively.

**Results:** Planimetry produced a significantly larger degree of variability (thus less repeatability) than digitizing ($p = .02$) and also produced smaller readings ($p = .00001$). Averaging over methods also indicated that photographic tracings produced smaller readings than raw tracings ($p = .019$).

**Conclusion:** For the wound sizes and shapes examined, tracings taken directly from the patients were found to be an inexpensive clinical and research assessment tool on which digitizing was conducted with a higher level of repeatability than planimetry. Further research is needed to determine if the current findings apply to a wider population within wound management clinics.

**Key Words:** Wounds; Planimetry; Reliability; Rehabilitation.

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IN RECENT YEARS, increasing interest has been focused on the techniques available for assessing and measuring wounds in the clinical setting. Katelaris and coworkers[1] highlighted the lack of a universally accepted method and noted that current methods to assess healing are unsatisfactory. The evaluation of wounds (and thus wound repair) has become a priority from both research and clinical perspectives. Therapists treating wounds need accurate, practical methods to describe and quantify wound size[2] if they are to accurately characterize wound healing. Reliable measurements assume particular importance for the clinician comparing the same wound on several occasions, and for the researcher evaluating a wound's response to therapeutic interventions.[3]

Researchers have monitored wound healing by means of histochemic studies, and microscopic histologic evaluation using bioassays of excised wound tissue. These methods are of particular interest to, and have been popularly used by, researchers to assess response to treatment during in vitro animal studies.[4-8] Macroscopic quantification of wounds has proven more popular for clinical studies in humans.[9-11] Such techniques have ranged from conventional methods (rulers, counting squares on gridded paper, and tracings taken directly from the wound site) to more sophisticated techniques, including structured video-image analysis, computer vision technology, three-dimensional laser imaging (of wound geometry), and planimetric or digitizing analysis of photographs and stereophotogrammetry.[12-15] Computerized noncontact techniques have addressed the issue of measuring wound volume, with some success.[12,13,15,16]

Despite the wide range of available techniques, clinical methods that are both accurate for the researcher and minimally invasive and comfortable for the patient are lacking. Studies comparing the reliability and accuracy of instruments designed to assess wound surface area are few.[17] Therefore we undertook this study to compare directly two separate methods of measurement (planimetry and digitizing) when carried out on two assessment procedures, that is, tracings taken directly from the patient's wound (raw tracing) and from photographs of the patient's wound (photographic tracing). Thus the concepts of assessment and measurement were dually investigated. Statistical tests performed on data taken on two separate days allowed the "best" method to be identified, based on independent variability and mean analyses.

## METHODS

After research approval by the University of Ulster's Research Ethical Committee, seven patients (4 women, 3 men; mean age ± standard error of the mean [SEM] 63.1 ± 5.0yrs), with a total of 11 wounds (area, 0.1 to 18.8cm$^2$) were selected for this study (table 1). Patients were in regular attendance at the Podiatry Clinic at Belfast City Hospital for management of

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**Table 1: Summary of Patient Characteristics and Wound Types**

| Wound | Patient Age (yrs) | Patient Category | Wound Type | Wound Site |
|---|---|---|---|---|
| w1 | 77 | Vascular | Ischemic | Right 1st toe, peri-ungual area |
| w2 | 69 | IDDM | Neuropathic/Ischemic | Medial border of right 1st toe |
| w3 | 47 | IDDM | Neuropathic | Right plantar anterior to heel |
| w4 | 47 | IDDM | Neuropathic | Lateral border of right foot |
| w5 | 44 | Vascular | Ischemic | Interdigital, between right 4th and 5th toes |
| w6 | 60 | Vascular | Ischemic | Medial border of left 1st nail |
| w7 | 72 | Vascular | Ischemic | Right posterior gaiter area of leg |
| w8 | 72 | Vascular | Ischemic | Right posterior heel |
| w9 | 71 | IDDM | Neuropathic/Ischemic | Apex of right 2nd toe |
| w10 | 71 | IDDM | Neuropathic/Ischemic | Apex of left 1st toe |
| w11 | 71 | IDDM | Neuropathic/Ischemic | Dorsal aspect of left 2nd toe |

Abbreviations: w, wound; IDDM, insulin-dependent diabetes mellitus.

these wounds. We recruited men and women according to these criteria: wound of any etiology; wound located anywhere on lower leg or foot; patient able to give written consent. Uncompliant patients were excluded from the study. Written informed consent was obtained from all patients before the start of the study after the nature and purpose of the research were explained to them.

Patients were required to attend two wound assessment sessions (Session 1, Session 2) separated by a period of 2 weeks. This interval was chosen because it allowed us to investigate reliability and wound size within each of the two time points (sessions). We also considered that 2 weeks between sessions would allow time for typical changes in wound size to occur. Throughout the study, routine treatment regimes were not altered and patients continued to receive the standard program of wound care as decided by the specialist podiatrist at the outpatient clinic. During both sessions, wound assessment was carried out by a single investigator as described below.

## Wound Tracing Procedures

***Raw tracings.*** A single tracing of each wound was made; all tracings were performed by an independent investigator to exclude interrater variability, which was not assessed in the present study. Before tracings were performed, the treating podiatrist thoroughly debrided surrounding callus (where present) and necrotic material to better define the boundary between epithelium and granulation tissue. Tracings were made by placing a highly conformable transparency[a] directly over the wound (avoiding movement and distortion), and making a tracing of the perimeter of the subjective wound margins onto the transparency with an indelible fine-tipped pen. A separate transparency was used for each wound. All tracings of a given wound were conducted twice: on 1 day at Session 1, and on another day 2 weeks later for Session 2.

***Photographic tracings.*** Wounds were photographed with a Nikon Nikkormat FT2[b] single lens reflex camera equipped with a 55mm Micro Nikkor f/2.8 macro lens[b] optically optimized for close-up work at small apertures. The camera was loaded with 200 ISO 35-mm print film[c] and a ring flash[d] provided a soft, shadowless frontal light. Five photographs were taken at each session at apertures f/8, f/11, f/16, f/22, f/32. Shutter speed was fixed at 1/125sec to synchronize with the flash. The photograph with the most acceptable visual detail was chosen and a single wound tracing was made from it. A 4-cm linear measurement scale[a] was included in each photograph's field to allow calibration during subsequent measurement procedures.

## Measuring Wound Surface Area

Wound surface areas were quantified for all tracings and photographs using planimetry and digitizing methods. This task, conducted over several days after each session, was performed after raw tracing were made and photographs were developed.

***Wound area calculated by planimetry.*** A Planix 7 digital planimeter[e] was used to calculate areas from the two tracings of each wound (raw tracing and photographic tracing). Scaling of the planimeter was required for photographs only; for this, scales were calculated by measuring what corresponded to 2cm on the scale bar in the photograph, and then converting to what this actually measured on a ruler. The scale of 1:1/measured distance was scaled into the planimeter. For raw tracings, (where scaling of the planimeter was not required) resolution of planimeter measurements was 0.1cm (ie, one decimal place).

***Wound area calculated by digitizing.*** Digitizing was carried out in two stages on an IBM-compatible personal computer. In the first stage the area of the wound was digitized from the two trace-types (raw tracing and photographic tracing). A computer-linked A3 digitizing table[f] and digitizer[g] using a four-button mouse was used to quantify wound surface area. A University of Ulster software program (DIGIT) written in Qbasic (Quickbasic)[18] was employed; the tracing on the tablet was secured and a prompt for output filename was used to store the coordinates of the wound outline. The scale bar was also digitized, because distances and angles varied for each photographic tracing: the digitized bar was used to determine the scale for area calculation. The wound's outline was digitized and terminated with mouse button three and all coordinates (both wound and scale bar) were written to an output file for subsequent area calculation. For raw tracings, scaling was not essential and 2 points at a distance of 2cm apart served as the start and end points. The program references these start/stop points during the digitizing process, relating them to the start and end points of the scale bar and the coordinates of the outer edge of the wound area. Software for the second stage (processing the calculations for wound area) was specifically developed for this purpose (also in Qbasic[18]) by the computer services department of the University of Ulster.

To determine the repeatability, and thus the reliability, of the two methods of measurement (planimetry and digitizing), a series of repeated recordings were made, in which both methods were applied on all tracings. Planimetry and digitizing were replicated three times on each raw and photographic wound tracing taken at Sessions 1 and 2. Thus 3 repeated measurements of the 2 methods were performed on the 2 trace-types for the 11 wounds. This process of repeated recordings is summarized in figure 1. From this raw data, two independent analyses were carried out.

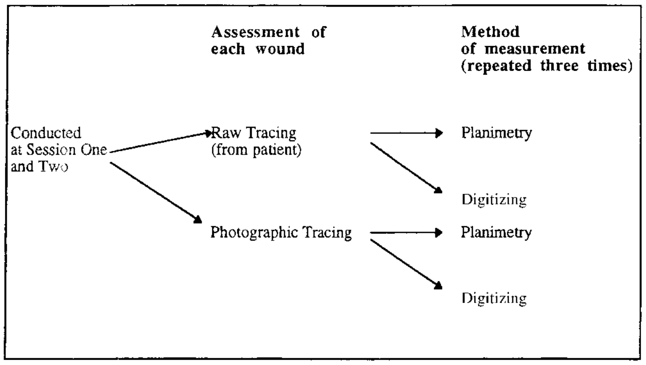


**Fig 1. The protocol for repeated recordings.**

## Data Analysis

Statistical analyses were carried out in two stages using the Statistical Calculator (SC) program.[19] Both analyses investigated the same factors: methods (planimetry vs digitizing), and trace-type (raw tracings vs photographic tracings).

***Logged coefficient of variation (logCV).*** The logCV was calculated for all raw and photographic tracing data from the 3 repeated recordings. The coefficient of variation (defined as the ratio of standard deviation to the mean) was used to compare reliability across the 4 combinations of trace type (raw tracings vs photographic tracings) and measurement method (digitizing vs planimetry).

***Logged means.*** Each mean, like each CV, was based on 3 measurements from a single tracing. These mean values were calculated to determine if the methods differed, on average, in the measured absolute wound sizes (either overall or at a specific time), and to see if the combinations of method with trace type were equally able to detect wound size changes over sessions.

A 3-factor repeated-measures analysis of variance (ANOVA) ($p < .05$) was conducted on all data with Simple main effects tests carried out where appropriate. Both analyses were relevant to the question of which method (planimetry or digitizing) and which type of assessment (raw tracings or photographic tracings) was "best." Thus "best" may refer either to lower measurement variability (and thus more repeatability), or to the ability to detect a decrease in wound size when another technique was not capable of doing so.

## RESULTS

All findings are discussed from logged data, because of systematic positive skew and some substantial outliers on the original scale (figs 2, 3). In the case of CV, there was considerable difference in variability across conditions on the original scale (see fig 2B), which was reduced, if not altogether eliminated, by the log transform (see fig 2A).

### Analysis 1: Logged Coefficient of Variation

Findings for the measurement methods (tables 2, 3) showed a significant method effect (see table 3) for planimetry versus digitizing. Averaging over both trace-type and session, these methods differed significantly in the measurement variability. Planimetry was more variable than digitizing (see table 2, values with ▲ and ●, where the higher unlogged CV value corresponds to greater variability).

Although no statistically significant trace-type effect existed, pooled logged mean CVs for raw tracings and photographic tracings indicated larger variation for raw tracings (see ■, table 2).

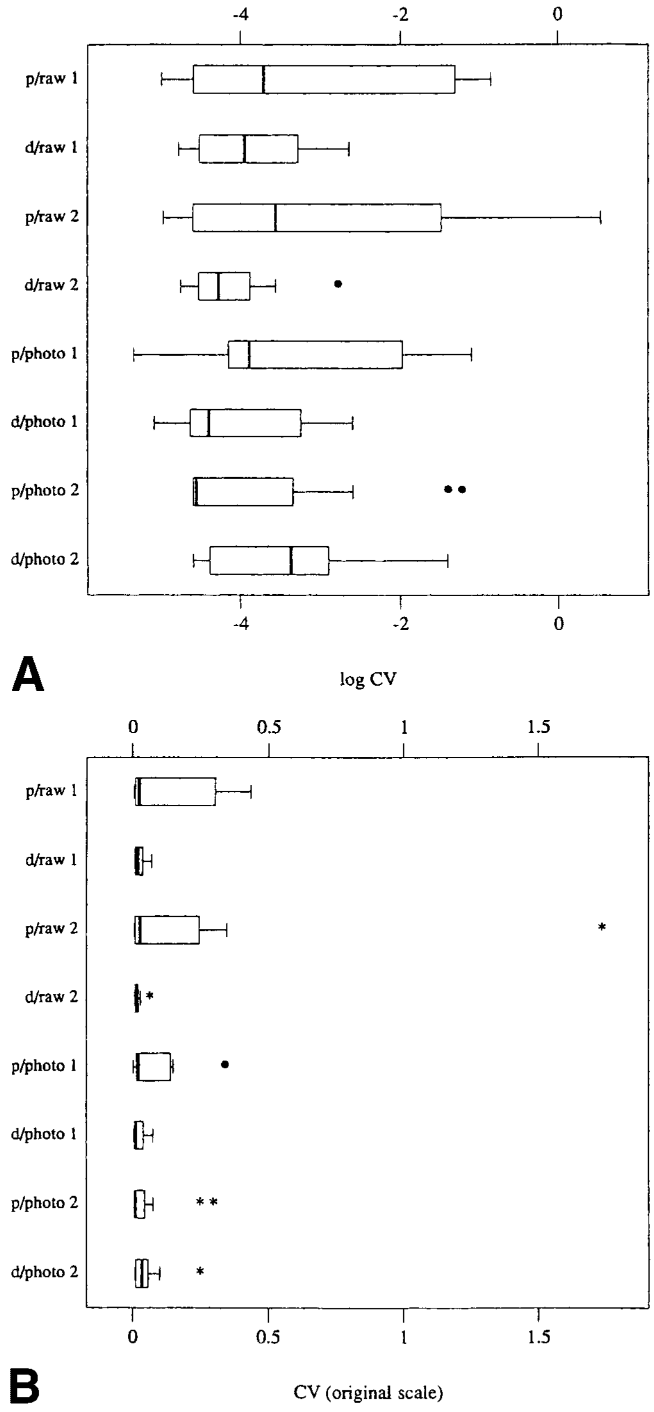


**Fig 2. Coefficient of variation (CV) values: (A) logCV for raw tracings and photographic tracings; (B) untransformed CV for raw tracing and photographic tracings. The box-ends show data quartiles; the bar between them is the median; outliers are plotted as stars if they are more than 3 interquartile ranges outside the quartiles, and as circles if between 1.5 and 3 interquartile ranges outside the quartiles; the "whiskers" go out to the most extreme observations that are not plotted separately as outliers. Abbreviations: p, planimetry; d, digitizing; raw, raw tracing; photo, photographic tracing; 1, Session 1; 2, Session 2.**

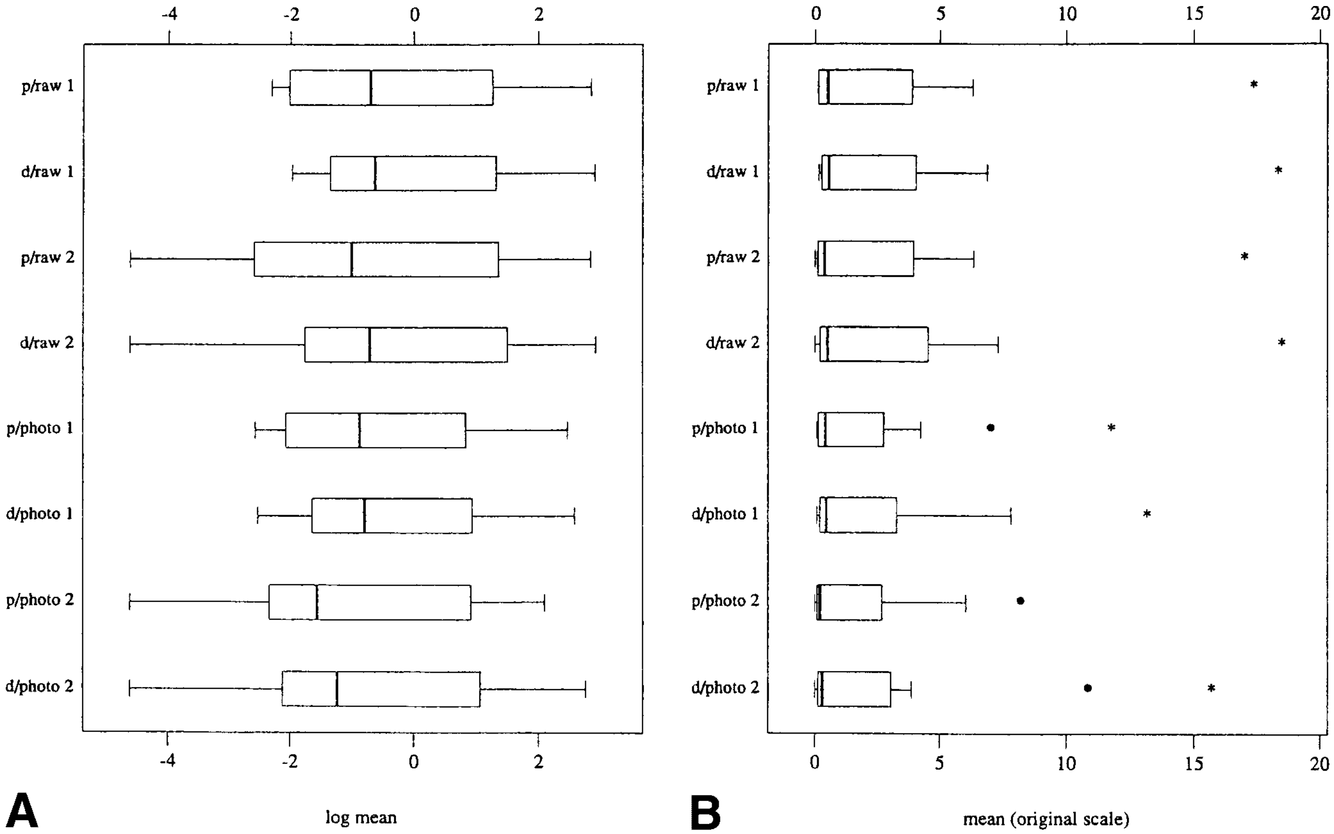


**Fig 3. Mean values: (A) log means for raw tracings and photographic tracings; (B) untransformed means for raw tracing and photographic tracings. The box-ends show data quartiles; the bar between them is the median; outliers are plotted as stars if they are more than 3 interquartile ranges outside the quartiles, and as circles if between 1.5 and 3 interquartile ranges outside the quartiles; the "whiskers" go out to the most extreme observations that are not plotted separately as outliers. Abbreviations: p, planimetry; d, digitizing; raw, raw tracing; photo, photographic tracing. 1, Session 1; 2, Session 2.**

A significant method times trace-type interaction was observed (see table 3), indicating that the difference in measurement variability between the two methods differed for the two trace-types (fig 4); in terms of methods, digitizing produced less variability for both raw and photographic tracings than planimetry. On consideration of trace-types, planimetry produced less variability with photographic tracings, while digitizing produced less variability with raw tracings (see fig 4). This significant method times trace interaction was further investigated by carrying out a Simple main effect test to establish for which of the trace-types the difference in methods was significant. This analysis demonstrated that a significant difference in methods existed only for raw tracings (see table 3).

**Table 2: Mean LogCV and Its Equivalent on the Original Scale**

| Trace Type | Planimetry Method Logged/ Unlogged | Digitizing Method Logged/ Unlogged | Pooled Mean for Trace-Type* Logged/ Unlogged |
|---|---|---|---|
| Raw tracing | −2.945/.053 | −4.016/.018 | −3.481/.031■ |
| Photographic tracing | −3.514/.03 | −3.769/.023 | −3.642/.026 |
| Pooled mean for method† | −3.230/.04▲ | −3.893/.02● | |

* Averaging over method.
† Averaging over trace-type.
▲,● The higher unlogged CV value corresponds to greater variability.
■ Raw tracings have larger variation than photographic tracings.

No change in variability was seen between Sessions 1 and 2, averaging over methods and trace-types as indicated by a nonsignificant session effect (see table 3).[9]

## Analysis 2: Logged Means

Tables 4 and 5 summarize data for logged means. As in the previous analysis for logged CVs, a significant method effect existed (see table 5). Therefore, averaging over both trace-type and session, the methods differed. Table 4 summarizes results of logged means and indicates that planimetry produced smaller means than digitizing (see values with ▼ and ◆).

Also, in this analysis there was a significant trace-type effect (see table 5). Here, the photographic tracings produced smaller means than raw tracings (see ⬮, table 4). The session effect was not significant and the method times session and trace-type times sessions interactions were also nonsignificant (see table 5); thus there was no convincing evidence of a decrease in wound size between sessions, either overall or for specific methods or trace-types. Analysis of logged means did not demonstrate a method times trace interaction, therefore regardless of the type of tracing chosen on which to measure, the method of planimetry produced smaller means.

## Summary of Findings

These can be succinctly described: planimetry produced a significantly larger degree of variability than digitizing ($p = .02$, table 3) and also produced smaller readings ($p = .00001$, table

**Table 3: Summary of ANOVA Output of LogCV Data**

| Source | Sum of Squares | *df* | Mean Square | *F* | *p* |
|---|---|---|---|---|---|
| Wound | 33.431 | 10 | 3.343 | | |
| Method | 9.679 | 1 | 9.679 | 7.47 [1, 10] | .021* |
| Wound × method | 12.953 | 10 | 1.295 | | |
| Session | .005 | 1 | .005 | .00 [1, 10] | .967 |
| Wound × session | 28.391 | 10 | 2.839 | | |
| Method × session | .691 | 1 | .691 | .39 [1, 10] | .546 |
| Wound × method × session | 17.733 | 10 | 1.773 | | |
| Trace-type | .570 | 1 | .570 | .83 [1, 10] | .382 |
| Wound × trace-type | 6.832 | 10 | .683 | | |
| Method × trace-type | 3.665 | 1 | 3.665 | 5.53 [1, 10] | .041* |
| Wound × method × trace-type | 6.631 | 10 | .663 | | |
| Session × trace-type | .051 | 1 | .051 | .07 [1, 10] | .803 |
| Wound × session × trace-type | 7.769 | 10 | .777 | | |
| Method × session × trace-type | 2.884 | 1 | 2.884 | 2.03 [1, 10] | .184 |
| Wound × method × session × trace-type | 14.188 | 10 | 1.419 | | |
| Total | 145.473 | 87 | | | |

* Statistically significant $p < .05$.

5). It was also shown that photographic tracings produced smaller readings than raw tracings ($p = .019$, table 5).

## DISCUSSION

This study investigated two types of wound measurement (planimetry and digitizing) performed on two methods of wound assessment (raw tracings directly from the wound and photographic tracings). Findings showed a significant difference in the amount of variability, and thus repeatability, between the two methods, with planimetry being more variable than digitizing. A significant difference was seen in the mean surface areas obtained by the two trace-types, with photographic tracing producing smaller means than raw tracing.

The lack of a statistically significant session effect for both logged mean and logCV analyses was somewhat unexpected. In the absence of other independent clinical evidence, it appears that wound size did not change between Session 1 and Session 2, although the possibility of a very small change in wound size, too small to detect by either method or trace-type, cannot be excluded.

The need to qualitatively evaluate wound measurement methods has been highlighted elsewhere,[3] along with the importance of reliability in any treatment intervention.[20] Because wound tracings are required both to establish a surface area value and to monitor change resulting from a particular intervention, repeatability was considered an integral factor in

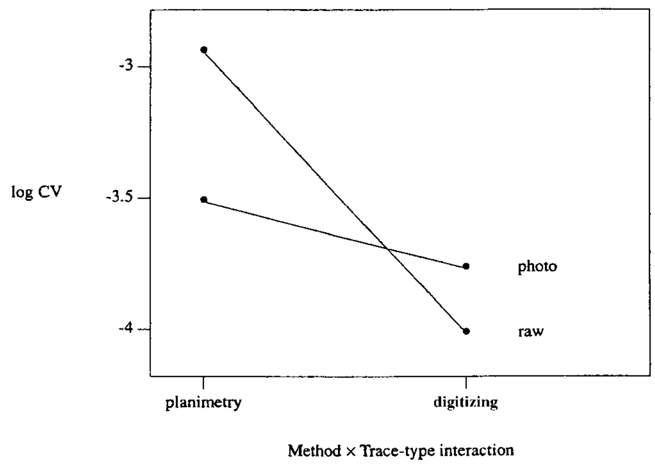


**Fig 4. Interaction plot for mean logCV values for method (planimetry and digitizing) times trace-type (raw tracings and photographic tracings). Abbreviations: photo, photographic tracing; raw, raw tracing.**

choosing the measurement method—whether for research purposes or routine clinical practice.

The results of the present study are interesting: the method effect observed in the logCV analysis (see table 3) and the method times trace-type interaction (see table 3) were both significant ($p = .021$ and $p = .041$, respectively). The degree of variability was determined not only by the choice of measurement method (planimetry or digitizing), but also by the trace-type (raw tracing or photographic tracing); for example, planimetry was more variable than digitizing, and that variability was much greater for raw tracings (see table 2). The logCV analysis indicated that digitizing produced the least variability overall, with the least variability when measurements were performed on raw tracings. Similar observations have also been reported by Majeske[20] where repeatability of the measurement was greatest with digitizing of a raw tracing (in contrast to planimetry also performed on raw tracings). However, no significant difference in variability between the two trace-types was observed in the present study, when averaging over both methods.

In the logged mean analysis, planimetry produced significantly smaller means regardless of the trace-type used. Furthermore, the additional significant trace effect indicated that photographic tracings produced the smaller means. Thomas and Wysocki[21] also observed a significant difference in terms of wound size between planimetry and digitizing methods when these methods were applied to tracings from the patient and photographic tracings. These authors noted that, despite a high

**Table 4: Log Mean and Its Equivalent on the Original Scale**

| Trace Type | Planimetry Method Logged/ Unlogged | Digitizing Method Logged/ Unlogged | Pooled Mean for Trace-Type* Logged/ Unlogged |
|---|---|---|---|
| Raw tracing | −.601/.548 | −.341/.711 | −.471/.625 |
| Photographic tracing | −.878/.416 | −.646/.524 | −.762/.467⧫ |
| Pooled mean for method† | −.739/.478▼ | −.494/.610◆ | |

* Averaging over method.
† Averaging over trace-type.
⧫ Photographic tracings produced smaller means than raw tracings.
▼,◆ Planimetry produced smaller means than digitizing.

**Table 5: Summary of ANOVA Output of Log Mean Data**

| Source | Sum of Squares | df | Mean Square | F | p |
|---|---|---|---|---|---|
| Wound | 342.816 | 10 | 34.282 | | |
| Method | 1.326 | 1 | 1.326 | 62.39 [1, 10] | .00001* |
| Wound × method | .213 | 10 | .021 | | |
| Session | 8.318 | 1 | 8.318 | 3.14 [1, 10] | .107 |
| Wound × session | 26.520 | 10 | 2.652 | | |
| Method × session | .007 | 1 | .007 | .12 [1, 10] | .740 |
| Wound × method × session | .595 | 10 | .060 | | |
| Trace-type | 1.865 | 1 | 1.865 | 7.89 [1, 10] | .019* |
| Wound × trace-type | 2.365 | 10 | .236 | | |
| Method × trace-type | .004 | 1 | .004 | .12 [1, 10] | .733 |
| Wound × method × trace-type | .361 | 10 | .036 | | |
| Session × trace-type | $1.065 \times 10^{-6}$ | 1 | $1.065 \times 10^{-6}$ | .00 [1, 10] | .997 |
| Wound × session × trace-type | .925 | 10 | .092 | | |
| Method × session × trace-type | .001 | 1 | .001 | .1 [1, 10] | .760 |
| Wound × method × session × trace-type | .145 | 10 | .015 | | |
| Total | 385.461 | 87 | | | |

* Statistically significant $p < .05$.

degree of correlation between methods, differences existed in the absolute size of the wound. Their finding of wounds measured from direct tracings being 20% larger than the same wounds measured by photographs is similar to the present study, in which we found a 24% enlargement for raw tracings, compared with photographic tracings. The accuracy of photographic measurements has also been questioned by Plassman[22] who similarly noted a reduction in the values obtained by this method. These findings can partly be explained by the need to calibrate photographic tracings. Furthermore, photography represents only 2-dimensional and uniplanar characteristics of wound surfaces, which are 3-dimensional and multiplanar—a shortcoming of photography highlighted as an additional error by Bohannon and Pfaller.[2] The present study's findings in the logged mean analysis support this concept, and may explain why smaller mean areas were obtained with photographs (especially for those wounds on contoured, multiplanar curved surfaces on the foot, toes, and lower limb). Others[2,17] have addressed inconsistencies with photographic images. For example, Ahroni and colleagues[3] have emphasized inconsistency from altering angles.

Although the results of the present study are clear, its limitations must be recognized. These include the number of wounds studied on a selected group of wound sizes and shapes with individual characteristics, on various locations of the foot and lower limb. These variations must be duly noted when comparing our results with other work, in generalizing current findings to the wider population, and for future work. Obviously comparisons between studies are difficult, because of varying designs and differences in statistical methods.[20]

## CONCLUSION

In the present study, digitizing (compared with planimetry) was identified as the more repeatable and thus more reliable measurement method for use with either raw or photographic tracing. Significantly larger mean surface areas were recorded with raw tracings (24% larger) than photographic tracings. Although photographic tracings potentially underestimate initial wound size, they provide a valuable visual record of serial wound healing, providing supplementary material beyond objective measurements. For this reason, as well as their versatility in busy outpatient departments, they are recommended as an additional qualitative form of wound assessment.

Both trace-types investigated in the present study were dependent on the investigator's clinical judgment; the measurement method relied on the researcher's ability to perform repeated measurements on these tracings, as well as the researchers skill, precision, and interest. The present study showed the importance of having a single investigator perform all assessment and measurement procedures. For any clinical trial, we recommend that researchers avoid mixing measurement methods (planimetry and digitizing) and also not mix trace-types.

Methods feasible for clinical practice often depend on other factors, including the availability of resources and practicality for clinical settings; therefore, methods chosen for research studies may be quite different from those used in clinical practice. Commercially available acetate tracing sheets are a rapid, inexpensive way to collect initial raw tracings for wound assessment. Digitizing can then be performed on the tracings with a high level of repeatability to quantify wound size for research purposes. The present findings are reported for a select group of wounds; further research is warranted before generalizing these findings to the wider population.

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## Suppliers

a. Seton Healthcare, Tubiton House, Oldham, OL1 3HS, England, United Kingdom.
b. Nikon Corp, Fuji Bldg, 2-3 Marunouchi 3-chome, Chiyoda-Ku, Tokyo 100-8331 Japan.
c. Kodak, Kodak House, Station Rd, Hemel Hempstead, Hertfordshire, HP1 1JU, England, United Kingdom.
d. Sunpack, ToCAD America Inc, 300 Webro Rd, Parsippany, NJ 07054-2882.
e. Graphtec Corp, 503-10 Shinano-cho, Totsuka-ku, Yokohama 244-8503 Japan.
f. Tamaya Techniques Inc, 2 Orion, Aliso Viejo, CA 92656-4200.
g. CalComp European Supplies Ltd, Crown House, The Metro Centre, Toutley Rd, Wokingham, Berkshire, RG41 1QN, England, United Kingdom.